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OPTIMIZATION OF MACHINING PARAMETERS IN DRILLING OF GFRP (GLASS/VINYL ESTER) COMPOSITES FOR REDUCTION OF DELAMINATION FACTOR

VEERESHCHANDRA. M. S[1], CHANDRAKANTH. N. S[2]
HEMANTH REDDY. A. C[3] & N. CHIKKANNA[4]

[1]*Assistant Professor, Department of Mechanical Engineering, Sri Jagadguru Chandrashekaranatha Swamiji Institute of Technology, Chickballapur, Karnataka, India*

[2,3]*7th Semester Department of Mechanical Engineering, Sri Jagadguru Chandrashekaranatha Swamiji Institute of Technology, Chickballapur, Karnataka, India*

[4]*Professor, Aerospace Propulsion Technology, Visvesvaraya Technological University, C P G S, Bengaluru Region, India*

ABSTRACT

The work reported on GFRP composites was mainly focused on evaluation of favorable machining environment during machining. Moreover, a number of approaches, namely optimization of the operating variables, appropriate selection of drill point geometry and development of special methods for making holes had been implemented. Motivated by the literature reports on GFRP composites, in this research work, the author proposes to use gray integrated with Taguchi to evaluate the optimal parametric combination in the drilling of GFRP composites. Furthermore, in this work, the drilling parameters are taken as spindle speed, feed and drill diameter, whereas machining evaluation characteristics are thrust, torque, delamination (both at entry and exit) and surface roughness.

KEYWORDS: GFR, Delamination, GFRP Composites, Drilling & Taguchi Technique

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Original Article

INTRODUCTION

Owing to their excellent mechanical and thermal properties, such as higher specific strength, enhanced specific modulus of elasticity, high damping factor, better resistance to corrosion, effective fatigue resistance and low thermal expansion coefficient, Glass Fiber Reinforced Polymer (GFRP) composites are extensively used in manufacturing industries especially in aircraft, aerospace, and automobile industries[1]. Therefore, it is imperative to understand the machine ability behavior of these composites [2]. Drilling is widely used to assemble the components in the aforementioned industries. But machining of these composites is dissimilar to conventional metals due to their isotropic nature and in-homogeneity [3]. Major drawbacks of these composites in machining are fiber pull out, delaminating and burring of fibers. Thus, selection of appropriate process parameters is of significant concern in the machining of (GFRP) composites [4].

During drilling, delamination occurs at the entry and exit planes of the workpiece. These are called peel-up and push-out delamination. Two different mechanisms are responsible for delamination on each side of the laminate [6]. Peel-up occurs as the drill enters the laminate. That is, as the cutting edge of the drill comes into contact with the laminate, the cutting force acting in the peripheral direction is the driving force for delamination [7]. It generates a peeling force in the axial direction through the slope of the drill flute that results in separating the laminas from

each other forming a delamination zone at the top surface of the laminate [8]. Peel-up delamination occurs by sliding the pierced plies up the flutes of the drill similar to the action of a power screw.

MATERIALS AND METHODS

Materials

The glass/vinyl ester composites were fabricated by hand lay-up technique. The E-glass fabric has an average filament diameter of 12µm & aerial weight of 0.329 kg/m^2. The glass fiber supplied was coated with an emulsion based sizing agent to promote good chemical adhesion with the resin matrix. The Vinyl ester resin was supplied by Ciba-Geigy, Araldite-LY 556 and Amine Hardener HY 951. Fiber glass composite will be fabricated using wet hand lay-up process into flat panels measuring 250 mm x 250 mm with a thickness of 3 mm. The volume fraction of glass fiber was 65% and the porosity content about 2%. The composites were cured at room temperature without elevated temperature post curing.

Machine and Equipments

Machine type: Sensitive drilling machine Current: 16 A Voltage: 415 V, 3 Ph 50 Hz. Drill tool dynamometer Type: Two-component dynamometer, Max thrust force: 500 kgF Max torque: 20kgm. Toolmaker microscope, LC = 0.001 mm.

Methodology

The prepared FRP laminates were cut down to a size that could be enough to fit in a vice of the drilling machine using an electric saw machine. HSS drill tool was fixed to the chuck of the drilling machine. Drill tool dynamometer was fixed to the table of the drilling machine. The positions of the holes to be drilled were marked using a permanent marker. The spindle speed was varied by changing the belt positions of the stepped cone pulley and the feed rate was varied by changing the position of the lever and automatic feed technique was applied for conducting the drilling experiments. Drilling tests were carried out based on the procedure generated using the design of experiments. For each trial, thrust force and torque was measured using drill tool dynamometer. The maximum diameter of the damage zone around the hole was measured using toolmakers microscope. Delamination factor i.e. the ratio of the maximum diameter of the damage zone and the hole nominal diameter was calculated.

Plan of Experiments using Taguchi Technique

The drill tests were planned using the Taguchi technique considering three factors and three levels, for all the three samples as presented in Table 6.1. The array chosen was the L_{27}, which has 27 rows corresponding to the number of tests with 26 degrees of freedom with 9 columns at three levels. Factors and interactions are assigned to specific columns. The first column was assigned to the feed rate (f), the second to the spindle speed (v) and the third column to diameter of drill and remaining were the outputs. The outputs to be studied are delamination, thrust force and torque. The tests were repeated thrice, corresponding to a total of 81 tests, to allow the analysis of variance of the results.

Table 1: Main Factors and Their Levels Chosen for the Drilling Study

Sample	Main Factor	L 1	L 2	L 3	DOF
A	Feed rate (mm/rev)	0.104	0.211	0.315	2
B	Spindle speed, rpm	450	852	1860	2
C	Drill diameter, mm	2.5	3.5	4.5	2

RESULTS AND DISCUSSIONS

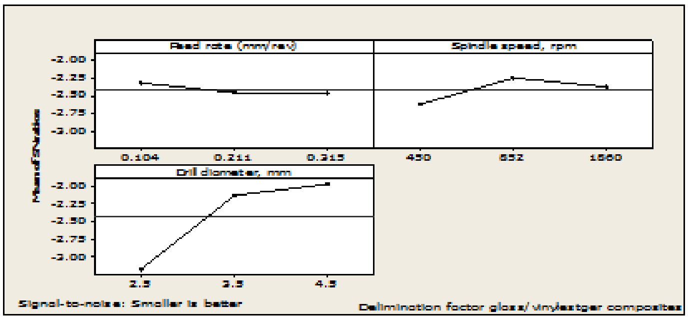

Figure 1: Effect of Feed Rate, Spindle Speed and Drill Diameter on Mean Delamination Factor of Glass/Vinyl Ester Composites

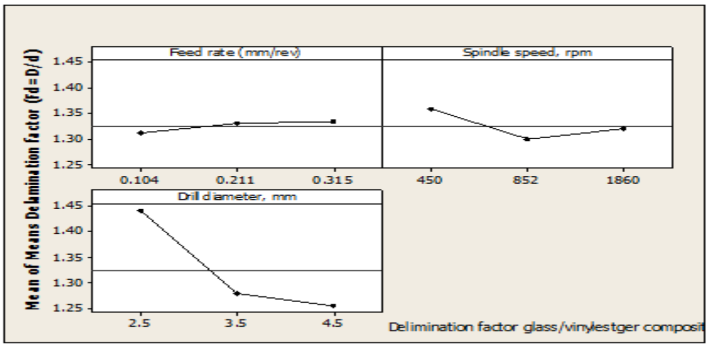

Figure 2: Effect of Feed Rate, Spindle Speed and Drill Diameter on Signal to Noise Ratio (Delamination Factor) of Glass/Vinyl Ester Composites

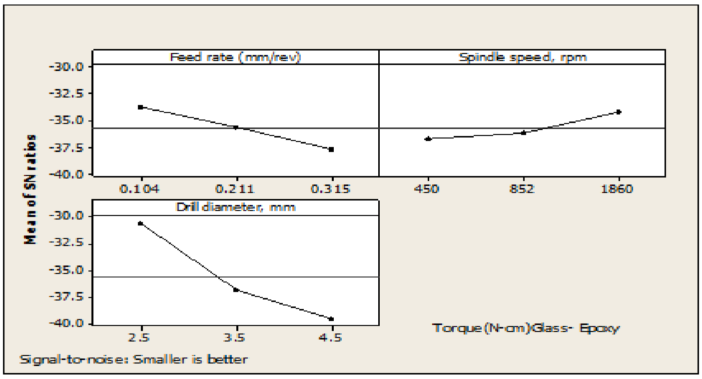

Figure 3: Effect of Feed Rate, Spindle Speed and Drill Diameter on Mean Signal-to-Noise Ratio (Torque) of Glass/Vinyl Ester Composites

Figure. 1 shows the multiple line graphs of main parameters (feed rate, spindle speed and drill diameter) and their responses on delamination factor. All the three curves are almost quadratic in nature and their influence on denomination more significant. Among the three, drill diameter is the very significant process parameter effecting on delamination followed by spindle speed.

The best choice appears to be the highest spindle speed to get low value of surface finish, and hence making the process robust to the cutting speed in particular. Since the interaction B × C is significant, it is purposefully, recommended to use the two ways B × C table to select their levels as per calculations. The two ways B × C table can be utilized to get the optimum combination of factor B and factor C to have the best result is B0C1 as explained. Hence, in order to get the

minimum value of surface roughness optimal combination will be A1B2C3 within the tested range. Similarly, As per Figure. 2 and Figure. 3 results were obtained for thrust force and torque respectively.

The dependency between the factors by using linear regressions is given in the table 2, 3 and 4 respectively. The results from Table 2 the delamination factor is influenced by the diameter of the hole by 70.91% for Glass/Vinyl ester. Whereas for all the three material system, consider the effect of speed rate and spindle speed on delamination factor is found negligible. And also the Interaction effects are found to be insignificant for all the cases.

Table 2: ANOVA Results of Delamination Factor for Glass/Vinyl Ester Composites

Factor	DOF	Sum of Squares (SS)	Mean Sum of Squares (MSS = SS/DOF)	F_{cal} = M.S/M. S_{error}	F_{tab} for 95% confidence	P% = SS/SST
A	2	0.019747	0.0098	3.7078	4.46	8.13%
B	2	0.008834	0.0044	1.6587	4.46	3.64%
C	2	0.172237	0.0861	32.3402	4.46	70.91%
AB	4	0.010955	0.0027	1.0284	3.84	4.51%
BC	4	0.003226	0.0008	0.3028	3.84	1.33%
AC	4	0.006605	0.0016	0.6200	3.84	2.72%
Error	8	0.021303	0.0026			8.77%
Total	**26**	**0.242907**				**100.00%**

Table 3: ANOVA Results of Thrust Force Factor for Glass/Vinyl Ester Composites

Factor	DOF	Sum of Squares (SS)	Mean Sum of Squares (MSS =SS/DOF)	F_{cal} = M.S/M. S_{error}	F_{tab} For 95% Confidence	P% = SS/SST
A	2	265.40	132.70	10.09	4.46	29.98
B	2	116.07	58.03	4.41	4.46	13.11
C	2	249.40	124.70	9.48	4.46	28.18
AB	4	33.70	8.42	0.64	3.84	3.81
BC	4	102.37	25.59	1.94	3.84	11.56
AC	4	13.03	3.25	0.25	3.84	1.47
Error	8	105.18	13.14			11.88
Total	**26**	**885.18**				**100.00**

Table 4: ANOVA Results of Torque Factor for Glass/Vinyl Ester Composites

Factor	DOF	Sum of Squares (SS)	Mean Sum of Squares (MSS = SS/DOF)	F_{cal} = M. S/M. S_{error}	F_{tab} for 95% Confidence	P% = SS/SST
A	2	265.40	132.70	10.09	4.46	29.98
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Error	8	105.18	13.14			11.88
Total	**26**	**885.18**				**100.00**

On the basis of the master plan generated and conducting experiment trials, the response (Thrust force) is obtained and tabulated in the Table 3. All the steps involved for the delamination factor and Thrust force remain same and hence the similarity computation was performed for torque also and tabulated in Table-4 it is clear that the feed rate influences the Thrust force to an extent of 29.98% and it is influenced by the spindle speed to an extent of 13.11%. As well as the influence of the drill diameter on Thrust force is to an extent of 29.18%.

QUALITY OF DRILLED HOLE

During drilling, delamination is observed at both the entrance and the exit known as peel-up and push-out delamination respectively, which can be seen dominating equally for the quality of the hole as shown in Figure. 4. As the tool enters through the FRP surface with twisting it increases peeling effect on fiber and is known as peel-up mechanism while the tool which process against the last layer of the FRP causes push-out. As the tool advances, FRP layers were pushed downwards vertically hence cutting strain increases on top of the surface and initiates crack growth in all directions. Due to the advancement of drill tool pullout fiber are also seen but are not affected by drilling. Before the machining happens completely the fibers or material unaffected spirals up.

Along with the Thrust force, peeling force act upwards during this situation peeling force in the axial direction propagates along the drill flute. As the denomination progress layer by layer the unaffected fibers resisting the lamina start bending and the bending increases further.

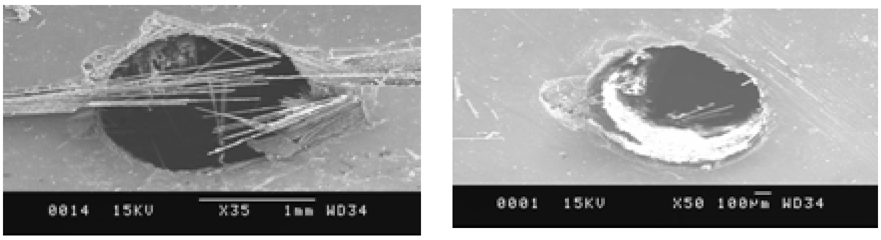

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Figure 4: Typical Photographs of Surface Drilled-Hole by Twist Drill (1)B_{EN} & (2) B_{EX} for Vinyl Ester laminates (EN and EX Are Entry and Exit of Drilled Hole Respectively)

CONCLUSIONS

By performing the optimization of drilling for glass/vinyl ester composite based on the responses (Thrust force, torque and delamination factor), the following conclusions are drawn.

- Among all the parameters in drilling, the more significant parameters influencing the responses (Thrust force, Torque, delamination factor) are drill diameter, spindle speed and feed rate.
- In the optimal condition, level 1 is the drill diameter, level 2 is feed rate and level 3 is the spindle speed.
- The minimum delamination, Trust force and torque during drilling are obtained with drill diameter of 4.5mm, spindle speed of 85.2rpm and feed rate of 0.104 mm.
- Near the drilled hole randomly scrapped glass fiber could be seen which is due to the fiber pull-out and due to the tool advancement FRP layers separate and dominate the delamination.

REFERENCES

1. *H P Chen, "Transverse shear effects on buckling and post buckling of laminated and Delaminated plats, AIAA Journal, vol. 31 (1) (1993) pp.163-169.*
2. *L Torre, J M Kenny and A G Mamalis, "Energy adsorbing behaviour of composites sandwich panels for civil transportation", In: Proceedings of the 20th Jubilee International SAMPE Europe Conference, 1997 April 13-15; Paris P.457.*

3. *C Hwu and J S Hu, "Buckling and Postbuckling of Delaminated Composites Sandwich Beams", AIAA Journal, Vol.30 (7) 1992, pp.1901-1909.*

4. *W C Kim, and C K H Dharan, "Facesheet Debonding Criteria for Composite Sandwich Panels under In-Plane Compression", Engineering Fracture Mechanics, vol.42 (4) (1992) pp.642-652.*

5. *R S Thomson, M Z Shah Khan and A P Mouritz, "Shear properties of a sandwich composites containing defects", Composite Structures, vol.42 (1998) pp.107-118.*

6. *Abrao A M, Faria P E et al. (2007). Drilling of fibre reinforced plastics, Journal of Materials Processing Technology, vol 186(1–3), 1–7.*

7. *G L Farley, "Crash energy absorbing sub-floor beam structures" Journal of the American Helicopter Society, vol.32 (4) (1987) pp.28-32.*

8. *R. Raja & Sabitha Jannet, Experimental Investigation of High Speed Drilling of Glass Fiber Reinforced Plastic (GFRP) Composite Laminates Made up of Different Polymer Matrices, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 7, Issue 6, November - December 2017, pp. 351-358*

9. *Engin S, Altintas Y et al. (2000). Mechanics of routing medium density fibreboard, Forest Production Journal, vol 50(9), 65–69.*

10. *Hull. D T. W. Clyne, 1996, An Introduction to composite materials, Second Edition, Cambridge University Press. König. W Ch. Wulf, P. Graß and H. Willerscheid, 1985 A theory of machining of fibre reinforced plastics. CIRP Annals-Manufacturing Technology, Vol. 34, pp 537-548.*

11. *Palanikumar, K., Karunamoothy, L., and Karthikeyan, R. 2004, Optimization of machining parameters for minimum surface roughness in turning of GFRP composites using design of experiment, Journal of. Material Science Technology, Vol. 20, No. 4, pp. 373-378.*